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In re Application of

Toshiya UEMURA, et al. Group Art Unit: 2815

Serial No.: 09/559,273 Examiner: Joseph H. Nguyen

Filed: April 27, 2000

For: LIGHT-EMITTING SEMICONDUCTOR DEVICE USING GROUP III NITRIDE COMPOUND

Honorable Commissioner of Patents
Alexandria, VA 22313-1450

VERIFIED TRANSLATION OF PRIORITY DOCUMENT

Sir:

Submitted herewith is a copy of Verified Translation of Priority Document for Japanese Application Number Hei. 10-150532 filed on May 13, 1998, upon which application the claim for priority is based.

Respectfully submitted,

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DECLARATION

I, Osamu Fujitani, a Japanese citizen of Marunouchi KS Bldg. 16F, 18-25, Marunouchi 2-chome, Naka-ku, Nagoya-shi, Aichi-ken, 460-0002, Japan, declare that I am familiar with the Japanese and English languages, and to the best of my knowledge and belief, the attached is a full, true, and faithful English translation of the Japanese Patent Application No. Hei-10-150532 filed on May 13, 1998, made by me as a requirement for U.S. Patent Application.

Osamu Fujitani

Osamu FUJITANI

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[TITLE OF THE INVENTION] Light-emitting Semiconductor Device Using Group III Nitride Compound

[NUMBER OF CLAIMS] 6

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[LIST OF FILING DOCUMENTS]

[TITLE OF THE DOCUMENT] Specification 1

[TITLE OF THE DOCUMENT] Set of Drawings 1

[TITLE OF THE DOCUMENT] Abstract 1

[REGISTRATED NUMBER OF POWER OF ATTORNEY] 9005344

[TITLE OF THE DOCUMENT] Specification

[TITLE OF THE INVENTION] LIGHT-EMITTING SEMICONDUCTOR DEVICE USING GALLIUM NITRIDE COMPOUND

[CLAIMS]

[CLAIM 1] A flip chip type of light-emitting semiconductor device having layers comprising gallium nitride compound semiconductor deposited on a substrate characterized in that

a thick positive electrode, which is connected to a p-type semiconductor layer and reflects light toward a sapphire substrate, comprises at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of these metals.

[CLAIM 2] A flip chip type of light-emitting semiconductor device using gallium nitride compound according to claim 1, wherein said thick positive electrode has a multi-layer structure comprising a plural kinds of metals.

[CLAIM 3] A flip chip type of light-emitting semiconductor device using gallium nitride compound according to claim 1 or 2, further comprising a first thin-film metal layer, comprising at least one of cobalt (Co), nickel (Ni), and an alloy including at least one of these metals, formed between said p-type semiconductor layer and said thick positive electrode layer.

[CLAIM 4] A flip chip type of light-emitting semiconductor device using gallium nitride compound according to claim 3, wherein a thickness of said first thin-film metal layer is in the range of 2 Å to 200 Å.

[CLAIM 5] A flip chip type of light-emitting semiconductor device using gallium nitride compound according to claim 3 or 4, further comprising a second thin-film metal layer, comprising at least one of gold (Au) and an alloy including gold (Au), formed between said first thin-film metal layer and said thick positive electrode layer.

[CLAIM 6] A flip chip type of light-emitting semiconductor device using group III nitride compound according to claim 7, wherein a thickness of said second thin-film metal layer is in the range of 10 Å to 500 Å.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[FIELD OF THE INVENTION]

The present invention relates to a flip chip type of light-emitting semiconductor device that comprises layers using gallium nitride group compound semiconductor formed on a substrate. Especially, the present invention relates to the device having a high luminous intensity and a low driving voltage.

[0002]

[DESCRIPTION OF BACKGROUND INFORMATION]

FIG. 4 shows a sectional view of a conventional flip chip type of light-emitting semiconductor 400. Each 101, 102, 103, 104, 105, 106, 120, 130, and 140 represents a sapphire substrate, a buffer layer of AlN, an n-type GaN layer, an emission layer, a p-type AlGaN layer, a p-type GaN

layer, a positive electrode, a protective film, a negative electrode having a multi-layer structure, respectively. And the thick positive electrode 120 which is connected to the layer 106 is a metal layer having a thickness of 3000 Å and being formed by metals such as nickel (Ni) or cobalt (Co).

[0003]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

Conventionally, to reflect light emitted from an emission layer 104 toward a sapphire substrate 101 effectively, a thick metal electrode is used as a flip chip type positive electrode 120.

However, a problem persists in luminous intensity. In the conventional device, metals such as nickel (Ni) or cobalt (Co) has been used to form the thick positive electrode 120. As a result, a reflectivity of visible (violet, blue, and green) rays whose wavelength is in the range of 380 nm to 550nm was insufficient, and the device could not obtain an adequate luminous intensity as a light-emitting semiconductor device.

[0004]

The present invention is completed to solve the problem described above. An object of the present invention is to obtain a light-emitting semiconductor device having a high luminous intensity and a low driving voltage.

[0005]

[MEANS TO SOLVE THE PROBLEMS]

To achieve the above objects, a first aspect of the

present invention is a flip chip type of light-emitting semiconductor device using gallium nitride compound semiconductor which comprises gallium nitride compound semiconductor layers deposited on a substrate and a thick positive electrode which is contacted to a p-type semiconductor layer and reflects light toward the substrate.

The positive electrode comprises at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of these metals. The thickness of the thick positive electrode should be preferably in the range of 100 Å to 5 μm.

[0006]

The second aspect of the present invention is to form a multi-layer structure comprising a plural kinds of metals in the thick positive electrode of the first aspect described above. When at least lower layer of the multi-layer in the thick positive electrode layer formed on or above i.e., comparatively close to the p-type semiconductor layer, comprises at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of these metals, the effect of the present invention is realized. Almost all layers including the lowest layer, which are placed in the range of 1000 Å at a lower side of the positive electrode, should further preferably comprise metals or alloy described above.

[0007]

The third aspect of the present invention is to form a

first thin-film metal layer comprising at least one of cobalt (Co), nickel (Ni), and an alloy including at least one of these metals between the p-type semiconductor layer and the positive electrode layer, in the first or second aspect.

[0008]

The fourth aspect of the present invention is to define a thickness of the first thin-film metal layer in the range of 2 Å to 200 Å in the third aspect. The thickness of the first thin-film metal layer should be preferably in the range of 5 Å to 50 Å.

[0009]

The fifth aspect of the present invention is to form a second thin-film metal layer comprising at least one of gold (Au) and an alloy including gold (Au) between the first thin-film metal layer and the thick positive electrode layer in the third or forth aspect.

[0010]

The sixth aspect of the present invention is to define a thickness of the second thin-film metal layer in the range of 10 Å to 500 Å in the fifth aspect. The thickness of the second thin-film metal layer should be preferably in the range of 30 Å to 300 Å.

Problems described above can be solved by carrying out these processes.

[0011]

[ACTIONS AND EFFECTS OF THE INVENTION]

Because each of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), and palladium (Pd) has a large reflectivity R ($0.6<R<1.0$) with respect to visible (violet, blue, and green) rays whose wavelength is in the range of 380 nm to 550nm, using one of these metals or an alloy including at least one of them to form the thick positive electrode layer improves a reflectivity of the positive electrode. Accordingly, the device of the present invention can obtain a sufficient luminous intensity as a light-emitting semiconductor device.

Because those metals and the alloy have a large work function, a contact resistance to the p-type semiconductor layer is small. That is, a light-emitting semiconductor device having a low driving voltage can be provided by using these metals.

And because these metals are precious metal or platinum group metal, a age deterioration for corrosion resistance against moisture, for example, is improved and an electrode of high quality can be provided by using these metals.

By forming the first thin-film metal layer, an adhesion between the first positive electrode layer and the p-type semiconductor layer is improved, and a light-emitting semiconductor device having a more durable structure can be provided. A thickness of the first thin-film metal layer should be preferably in the range of 2 Å to 200 Å. When the thickness of the first thin-film metal layer is less than 2

Å, a firm adhesion cannot be obtained, and when more than 200 Å, a light reflectivity of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of these metals, which form the thick first positive electrode layer, becomes insufficient.

Further, by forming the second thin-film metal layer, an adhesion between the first positive electrode layer and the p-type semiconductor layer is improved, and a light-emitting semiconductor device having a further durable structure can be provided. A thickness of the second thin-film metal layer should be preferably in the range of 10 Å to 500 Å. When the thickness of the second thin-film metal layer is less than 10 Å, a firm adhesion cannot be obtained, and when more than 500 Å, a high light reflectivity of the metal and alloy described above, which form the first positive electrode layer, cannot be used effectively.

[0012]

[DETAILED DESCRIPTION OF EXAMPLARY EMBODIMENTS]

The present invention will be described hereinbelow with reference to specific embodiments. The present invention is not limited to the embodiments.

(First Embodiment)

FIG. 1 illustrates a sectional view of a flip chip type of light-emitting semiconductor device 100. The semiconductor device 100 has a sapphire substrate 101 which has a buffer layer 102 made of nitride aluminum (AlN) having a thickness of 200 Å and a silicon (Si) doped n^{+}-layer 103

having a thickness of 4.0 μm with a high carrier concentration successively thereon.

And an emission layer 104 constructed with a multi quantum-well (MQW) structure made of GaN and $Ga_{0.8}In_{0.2}N$ is formed on the n^+-layer 103. A Mg-doped p-layer 105 made of $Al_{0.15}Ga_{0.85}N$ having a thickness of 600 Å is formed on the emission layer 104. Further, a Mg-doped p-layer 106 made of GaN having a thickness of 1500 Å is formed on the p-layer 105.

[0013]

A first thin-film metal layer 111 is formed by a metal deposit on the p-layer 106 and a negative electrode 140 is formed on the n^+-layer 103. The first thin-film metal layer 111 is made at least one of cobalt (Co) and nickel (Ni) having a thickness about 10 Å, and is adjacent to the p-layer 106. A positive electrode 120 is made of at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of them, having a thickness of about 3000 Å. The negative electrode 140 having a multi-layer structure is formed on an exposed portion of the n^+-layer 103 of high carrier concentration. The multi-layer structure is comprising following five layers: about a 175 Å in thickness of vanadium (V) layer 141; about 1000 Å in thickness of aluminum (Al) layer 142; about 500 Å in thickness of vanadium (V) layer 143; about 5000 Å in thickness of nickel (Ni) layer 144; and about 8000 Å in thickness of gold (Au) layer 145. A protective

film 130 made of SiO_2 is formed on the top surface.

As described above, when the positive electrode 120 is made of at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of these metals, a luminous intensity is improved by about 10 % to 50 % compared with a light-emitting semiconductor device 400 of prior arts which is shown in item number 1 and 2 of FIG. 3.

[0014]

(Second Embodiment)

FIG. 2 shows a sectional view of a flip chip type of light-emitting semiconductor device 200 of the present invention. The semiconductor device 200 differs from the device 100 described in the first embodiment only in forming a second thin-film metal layer 112 on the first thin-film metal layer 111. The second thin-film metal layer 112 is made of Au having a thickness of about 150 Å, which is formed by a metal deposit after the first-thin film metal layer 111 is formed, in the same way of forming the first thin-film metal layer 111 made of cobalt (Co) or nickel (Ni) having a thickness of about 10 Å.

Forming this second thin-film metal layer 112 between the first thin-film metal layer 111 and the positive electrode 120 enables the positive electrode 120 to be connected to the layer 106 more firmly.

[0015]

FIG. 3 shows a table to compare performances of each

flip chip type of light-emitting semiconductor devices 100, 200 and 400, respectively. The table of FIG. 3 also shows performances of a flip chip type of light-emitting semiconductor device, comprising a positive electrode 120 which is made of silver (Ag), directly contacted to the p-layer 106 without the first thin-film layer 111 in the first embodiment, shown in FIG. 3 (item number 3). As shown in this table, a luminous intensity of the light-emitting semiconductor device 100 or 200 in the present invention, which has the thick positive electrode 120 made of metal layers comprising at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of these metals, is improved by about 10 % to 50 % compared with the light-emitting semiconductor device 400 of prior arts which is shown in item number 1 and 2 of FIG. 3.

Further, with respect to the light-emitting semiconductor device 400 shown in item numbers 1 and 2, a first thin-film metal layer is not formed because the positive electrode 120 itself is made of cobalt (Co) or nickel (Ni), which ensures an adhesion between the thick positive electrode 120 and the layer 106 sufficiently. The light-emitting semiconductor device 400 shown in item number 1 and 2 of FIG. 3, which contains the thick positive electrode 120 made of cobalt (Co) or nickel (Ni), has a low relative luminous intensity because a reflectivity of metal elements which constitute the thick positive electrode 120

is small. Accordingly, superiority or inferiority of the relative luminous intensities shown in FIG. 3 is not due to the existence of the first thin-film metal layer 111. Conversely, when the thick positive electrode 120 is made of at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt), palladium (Pd), and an alloy including at least one of these metals, a large luminous intensity can be obtained in case that the first or the second thin-film metal layer 111 or 112 is not existed, as understood comparing item number 3 with item 4 of FIG. 3. The luminous intensity shows an excellent value although a adhesion between the thick positive electrode 120 and the layer 106 is inferior to some degree. That is because the first and the second thin-film metal layers 111 and 112 which absorb light do not exist.

[0016]

In the embodiment, the thick positive electrode 120 has a thickness about 3000 Å. Alternatively, the thickness of the thick positive electrode 120 can be in the range of 200 Å to 5 μm. When the thickness of the positive electrode 120 is less than 200 Å, a light reflectivity become insufficient. When the thickness is more than 5 μm, too much time and materials for deposit are required, which means that the thickness is of no use concerning a production cost performance.

[0017]

In the embodiment, the positive electrode 120 has a

single-layer structure. Alternatively, the positive electrode 120 can have a multi-layer structure. The positive electrode, 1.4 μm in thickness, can be formed by depositing, for example, about 5000 Å silver (Ag), about 800 Å nickel (Ni), and 8000 Å gold (Au), consecutively, on the GaN layer 106, the first thin-film metal layer 111, or the second thin-film metal layer 112. A light-emitting semiconductor device with sufficiently high reflectivity and luminous efficiency can be obtained by the positive electrode having this multi-layer structure.

[0018]

In the embodiment, the first thin-film metal layer 111 has a thickness about 10 Å. Alternatively, the thickness of the first thin-film metal layer 111 can be in the range of 2 Å to 200 Å. The thickness of the first thin-film metal layer 111 should be more preferably in the range of 5 Å to 50 Å. When the thickness of the first thin-film metal layer 111 is too small, function of binding the thick positive electrode 120 to the GaN layer 106 is weakened, and when too large, a light absorption is occurred therein and a luminous intensity is lowered.

[0019]

In the embodiment, the second thin-film metal layer 112 has a thickness about 150 Å. Alternatively, the thickness of the second thin-film metal layer 112 can be in the range of 10 Å to 500 Å. The thickness of the second thin-film metal layer 112 should be more preferably in the

range of 30 Å to 300 Å. When the thickness of the second thin-film metal layer 112 is too small, binding the thick positive electrode 120 to the first thin-film metal layer 111 is weakened, and when too large, a light absorption is occurred therein and a luminous intensity is lowered.

[0020]

With respect to the structure of the layers of the electrodes in all the embodiments, physical and chemical composition of each layer in the light-emitting semiconductor device is shown at the instant time of deposition. It is needless to mention that solid solutions or chemical compounds are formed between each layer by physical or chemical treatments such as a heat treatment to obtain a firmer adhesion or to lower a contact resistivity.

[0021]

In all the embodiments, the emission layer 104 has a MQW (multi-quantum well) structure. Alternatively, the emission layer 104 can have a SQW (single-quantum well) structure or a homozygous structure. Also, a III group nitride compound semiconductor layer of the light-emitting semiconductor device in the present invention can be formed of one of a quaternary, ternary and binary layer compound $Al_xGa_yIn_{1-x-y}N$ ($0 \le x \le 1$, $0 \le y \le 1$, $0 \le x+y \le 1$). In the embodiments, magnesium (Mg) is used as a p-type impurity. Alternatively, group II elements such as beryllium (Be) or zinc (Zn) can be used.

[BRIEF DESCRIPTION OF THE DRAWING]

[FIG. 1] A sectional view of a flip chip type of light-emitting semiconductor device 100 in accordance with the first embodiment of the present invention.

[FIG. 2] A sectional view of a flip chip type of light-emitting semiconductor device 200 in accordance with the second embodiment of the present invention.

[FIG. 3] A table to compare performances of each flip chip type of light-emitting semiconductor devices 100, 200 and 400 in accordance with the second embodiment of the present invention.

[FIG. 4] A sectional view of a light-emitting semiconductor device 400 of a prior art.

[REFERENCE NUMERALS]

101...sapphire substrate

102...aluminum nitride (AlN) buffer layer

103...n-type gallium nitride (GaN) layer

104...emission layer

105...p-type AlGaN layer

106...p-type GaN layer

111...first thin-film metal layer

112...second thin-film metal layer

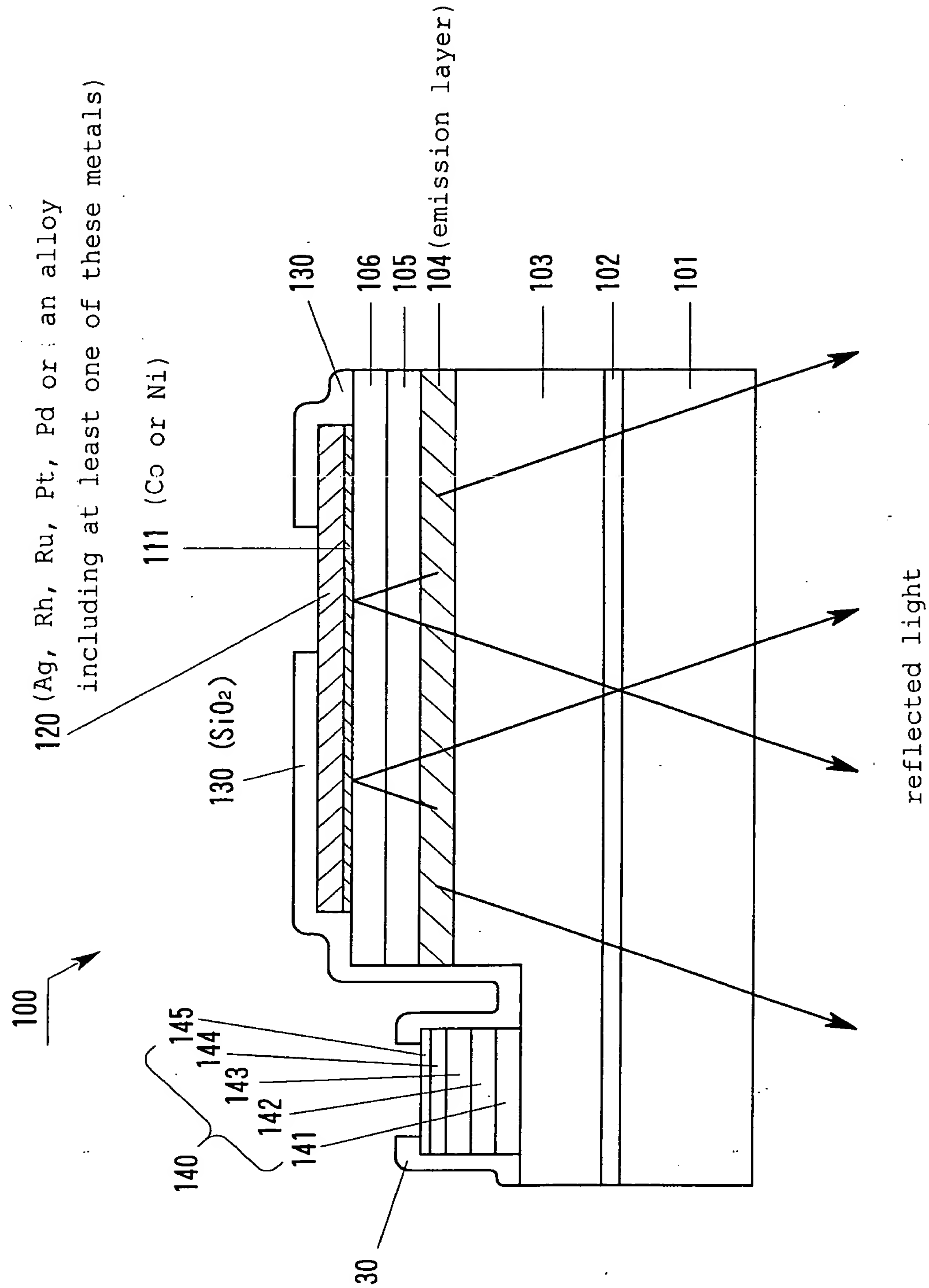
120...thick positive layer

130...protective film

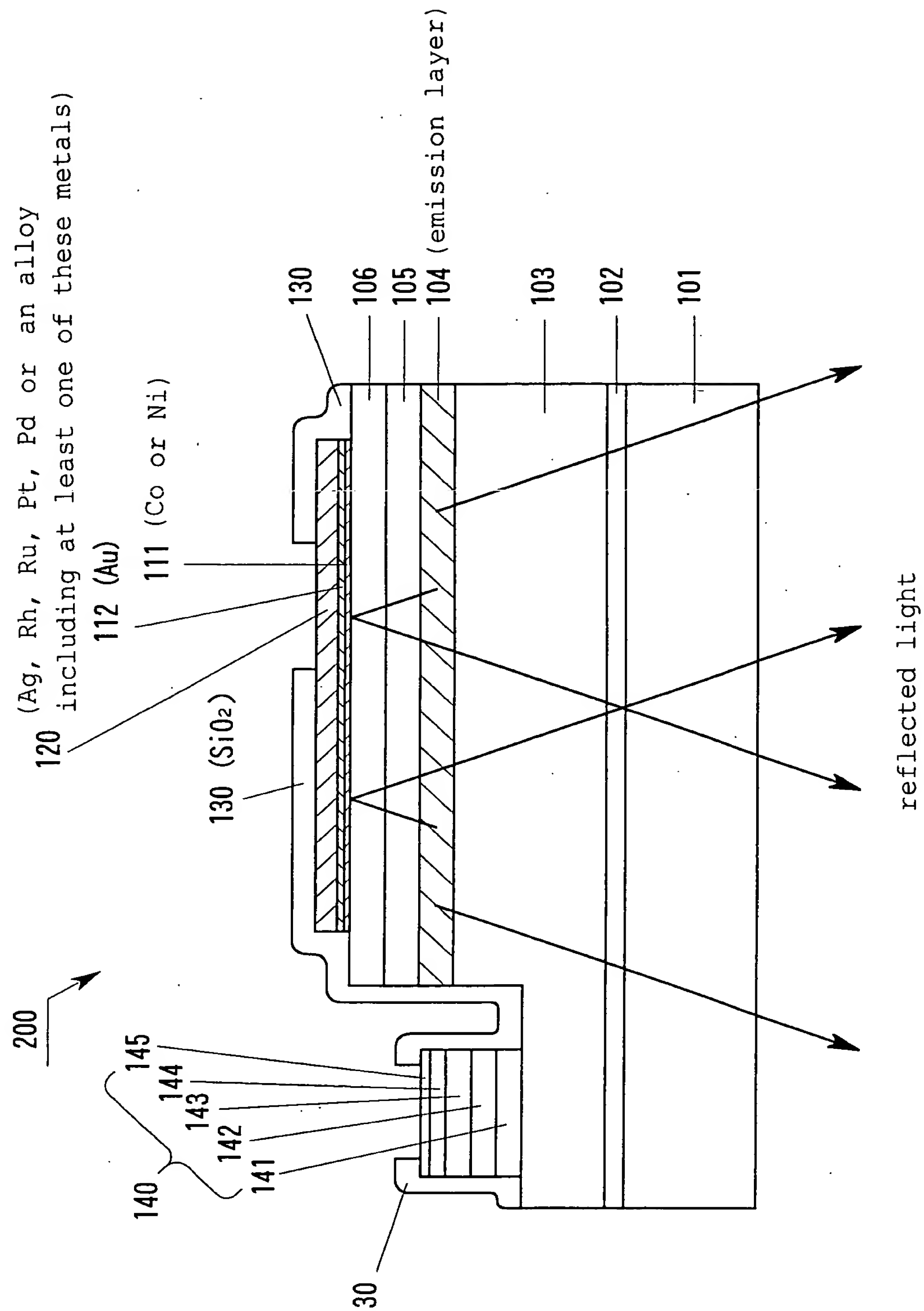
140...negative electrode with multiple layer structure

[TITLE OF THE DOCUMENT] Figures

[FIG. 1]



[FIG. 2]


(Ag, Rh, Ru, Pt, Pd or an alloy including at least one of these metals)
120
112 (Au)
111 (Co or Ni)
130 (SiO2)
130
106
105
104 (emission layer)
103
102
101
reflected light
200
145
144
143
142
141
140
130

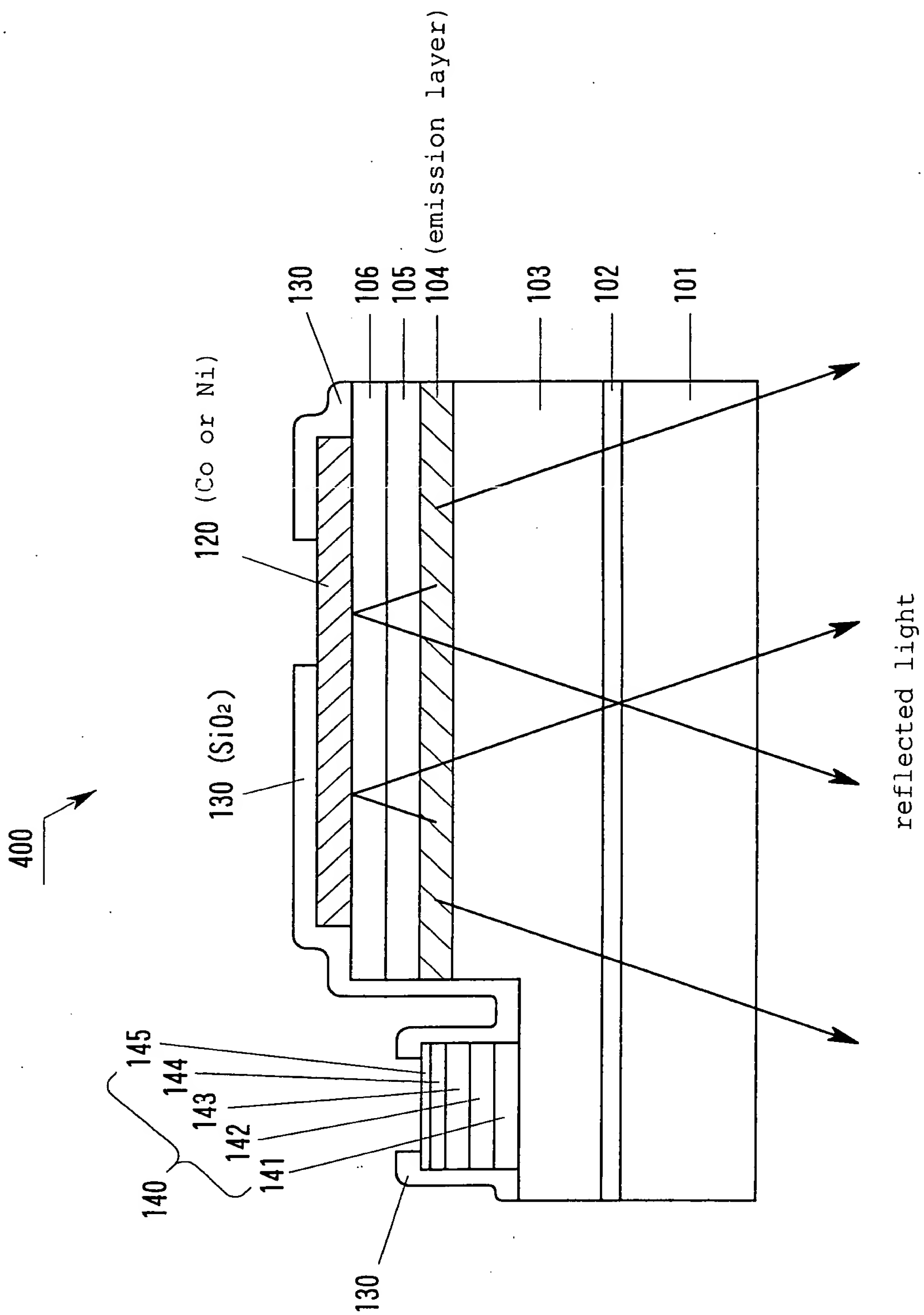
[FIG. 3]

Measured Result of Luminous Intensity

ITEM	TECHNOLOGY DIVISION	STRUCTURE	POSITIVE ELECTRODE	FIRST THIN-FILM METAL LAYER	SECOND THIN-FILM METAL LAYER	RELATIVE LUMINOUS INTENSITY	ADHESIVENESS
1	PRIOR ART	LIGHT-EMITTING DEVICE 400 (FIG. 4)	Co (3000 Å)	–	–	100	◎
2			Ni (3000 Å)	–	–	100	◎
3	PRESENT INVENTION		Ag (3000 Å)	–	–	160	○‾
4		LIGHT-EMITTING DEVICE 100 (FIG. 1)	Ag (3000 Å)	Co (10 Å)	–	150	○
5			Rh (3000 Å)	Co (10 Å)	–	130	○
6			Pt (3000 Å)	Co (10 Å)	–	110	○
7			Pd (3000 Å)	Co (10 Å)	–	110	○
8		LIGHT-EMITTING DEVICE 200 (FIG. 2)	Ag (3000 Å)	Co (10 Å)	Au (150 Å)	150	◎

◎ : EXELLENT ○ : GOOD ○‾ : inferior than GOOD but usable

[FIG. 4]


400
130
106
105
104 (emission layer)
103
102
101
120 (Co or Ni)
130 (SiO_2)
reflected light
145
144
143
142
141
140
130

[TITLE OF THE DOCUMENT] Abstract of the Disclosure

[SUMMARY]

[PURPOSE] To provide a light-emitting semiconductor device having high luminous intensity and low driving voltage.

[CONSTITUTION]

A flip chip type of light-emitting semiconductor device using gallium nitride compound comprising a thick positive electrode. The positive electrode, which is made of at least one of silver (Ag), rhodium (Rh), ruthenium (Ru), platinum (Pt) and palladium (Pd), and an alloy including at least one of these metals, is adjacent to a p-type semiconductor layer, and reflect light toward a sapphire substrate. Accordingly, a positive electrode having a high reflectivity and a low contact resistance can be obtained. A first thin-film metal layer, which is made of cobalt (Co) and nickel (Ni), or any combinations of including at least one of these metals, formed between the p-type semiconductor layer and the thick electrode, can improve an adhesion between a contact layer and the thick positive electrode. A thickness of the first thin-film metal electrode should be preferably in the range of 2 Å to 200 Å, more preferably 5 Å to 50 Å. A second thin-film metal layer made of gold (Au) can further improve the adhesion.

[SELECTED FIGURE] Fig. 1